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Experimental Study of Biomass Particle Combustion

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Abstract

An experimental study was conducted to investigate the combustion behavior of single cylindrical and spherical biomass particles with diameters from 1 to 3mm. Particles with different aspect ratios (similar diameter and volume) were produced for studying the influences of particle shape on the combustion process. The particles were combusted in a single particle reactor at temperatures in the range of 1200 C to 1600 C and oxygen concentration levels in the range of 5 to 20%. A CCD camera was used to record the whole combustion process.

Experimental Setup

- The set up mainly consists of a reactor, a burner, a flame detector and a gas supply system. The burner is a Blue Flame Technology 94 Jet Burner.
- The flow rates are controlled by mass flow controllers (MFCs) of the type EL-FLOW which is connected to a computer. The software Lab View 8.6 regulates and controlled the flow.
- The entire combustion process is recorded by using of a high performance camera which is located in the back of the reactor. The camera is an Allied Vision Technologies Stingray F-033 which is able to take 65 images per second in average.

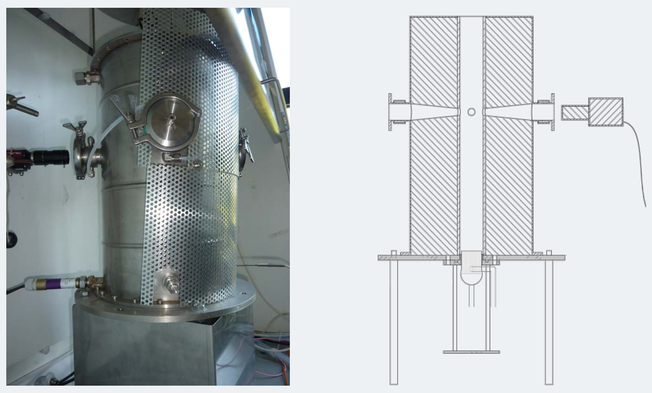


Fig 1. Setup

Experimental Procedure

- The temperature and oxygen profiles inside the reactor have been measured by inserting a thermocouple and a suction probe into the reactor in the desired location from the wall to the reactor center.
- A ceramic protection tube is applied to cover the particle and allows it to reach the center before it is ignited. The tube is made of Al2O3 with a thermal conductivity of 30 W/mK. The protection tube is inserted to the reactor first, then the particle on the platinum holder is inserted to the reactor through the protection tube from the opposing hole, and at the end, the protection tube is ejected from the reactor tube. All these steps are done very quickly (< 5s) and the heat transfer from the tube to the particle is negligible.

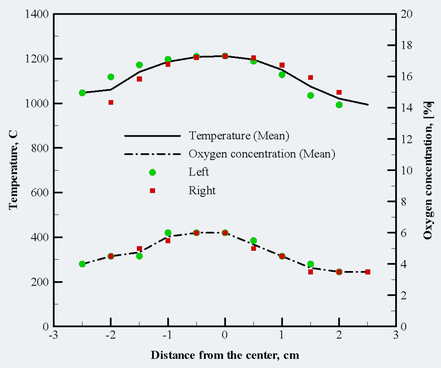


Fig. 2. Temperature and oxygen concentration profiles (T_{center}=1200C, $O_{2,center}$=6%)

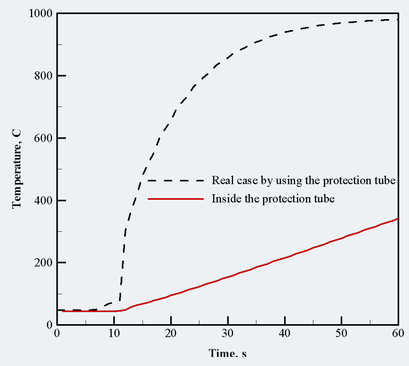
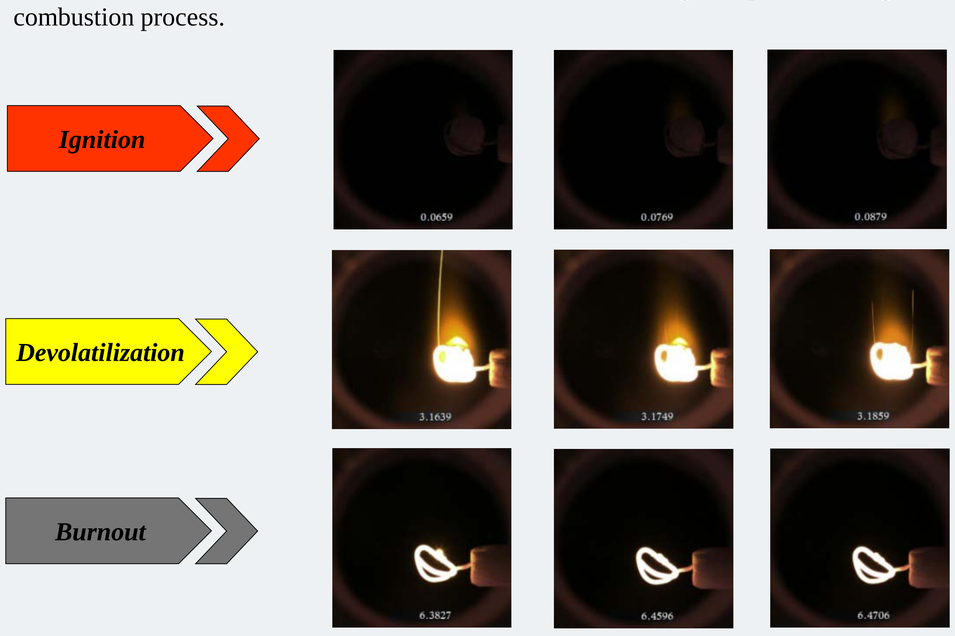


Fig. 3. Temperature variation vs. time inside the protection tube and reactor.

- Three different times can be determined from the resulted video, ignition time, total devolatilization time and burnout time. The criteria for determining the ignition, devolatilization and burnout time are based on the observation from the images captured during the whole combustion process.



Materials and Conditions

- The investigated fuel was a low ash content pine wood.
- All the shaped samples were weighed before the tests and there was less than 5% difference. Table 1 shows all the sizes, shapes and averaged masses of particle samples and Fig. 4 shows images of the produced particles with different shape and size.

Fig. 4. Samples

Table 1
Sample's size and shape information

Shape	d (mm)	L (mm)	AR	M (g)	S/V (mm-1)
Sphere	3.0	-	1	≈ 0.0125	2.0
Cylinder	2.08	4.16	2	≈ 0.0125	2.4
Cylinder	1.65	6.60	4	≈ 0.0125	2.7
Cylinder	1.44	8.65	6	≈ 0.0125	3.0
Cylinder	1.31	10.48	8	≈ 0.0125	3.2
Cylinder	3.0	6	2	0.0230	1.6
Cylinder	3.0	12	4	0.0490	1.5
Cylinder	3.0	18	6	0.0695	1.4

- It has been tried to provide conditions reasonably close to the conditions in a power plant burner. In the experiments, the temperature varies in the range of 1200 to 1600 C and the oxygen concentration changes from 5 to 20%.

Results and discussion

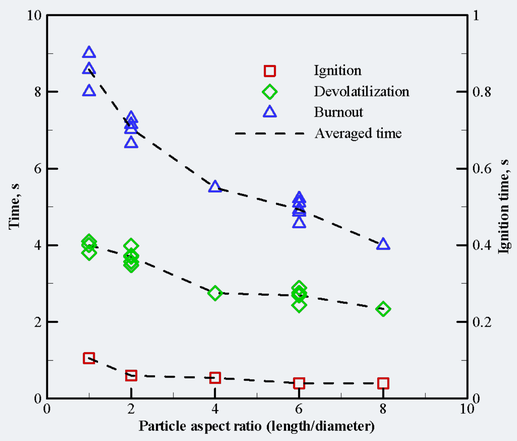


Fig. 4. Effects of particle shape on the conversion time of particles with similar mass (volume). T=1200C, O_2=20%, AR=1 refers to spherical particle.

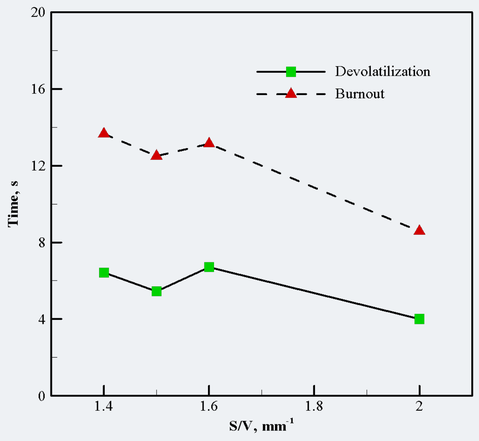


Fig. 5. Effects of particle shape on the conversion time of particles with similar diameter. T=1200C, O_2=20%, diameter of all particles is 3mm.

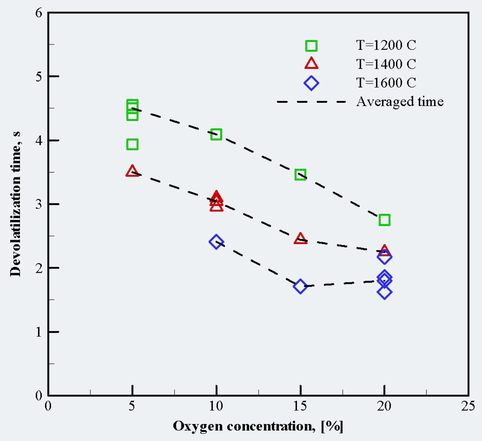


Fig. 6. Effects of surrounding conditions on the particle devolatilization time.

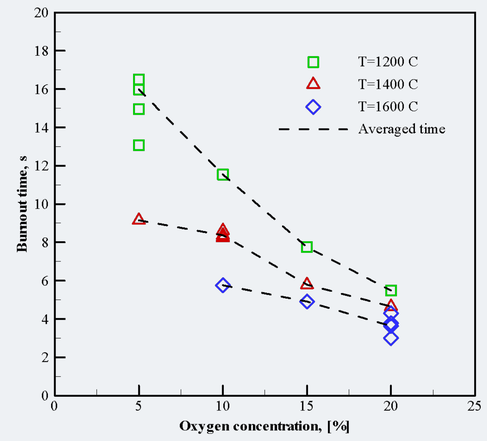


Fig. 7. Effects of surrounding conditions on the particle burnout time.

- ✓ The results showed that among the particles with similar volume and mass, spherical particles have the longest conversion time due to the fact that it has the lowest surface area to volume ratio compared to other shapes.
- ✓ From a practical point of view, particles are more likely to have similar diameter than mass in a power plant due to the milling grinding process. For the particles with similar diameter and different volume, spherical particle has the highest surface area to volume ratio and this value is almost the same for the cylindrical particles with different length. Hence the spherical particle is devolatalized and burnt out faster than cylindrical particles and there is no significant difference between different cylindrical particles with different length due to their similar surface area to volume ratio.
- ✓ Single cylindrical particles with an aspect ratio of 4 was combusted at different temperatures and oxygen concentration. The results indicated that the effects of temperature and oxygen concentrations are more remarkable for burnout time than devolatilization time. The influence of oxygen concentration is reduced by increasing the temperature.

Acknowledgements

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